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Water Sensitive Urban Design

Book 2 | PLANNING AND MANAGEMENT

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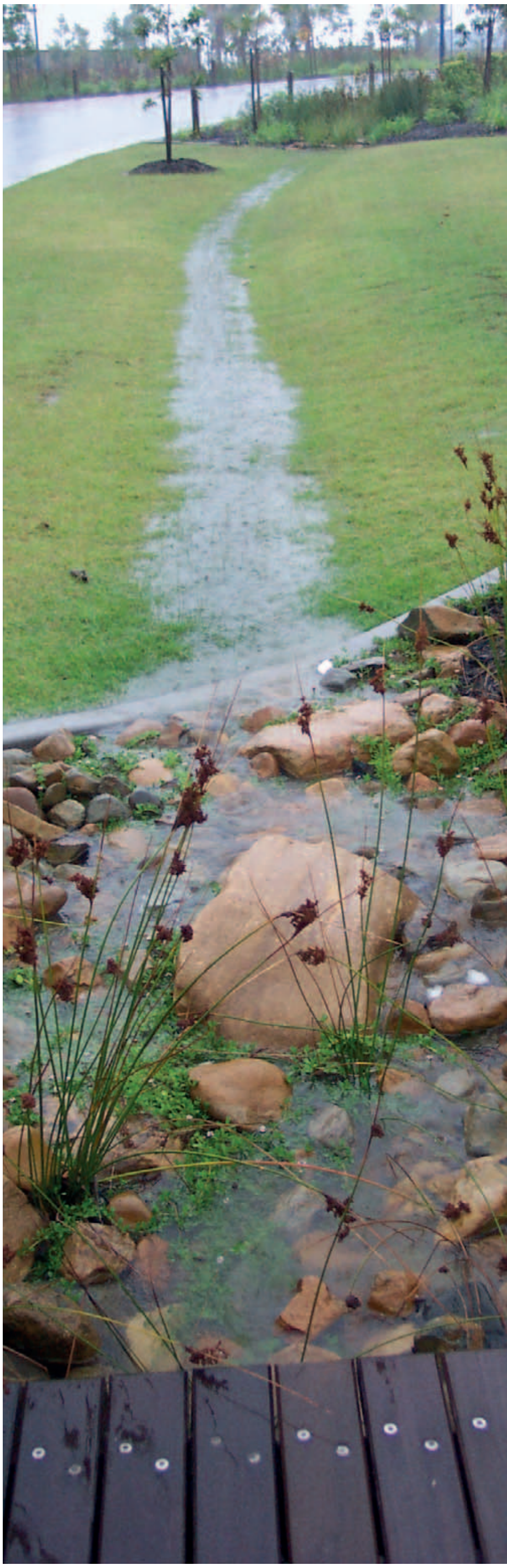


Bioswale

1 | Introduction

Proposed bioswale in median strip | Green Square Town Centre

Landcom has implemented a range of innovative WSUD initiatives which have achieved targets beyond the original WSUD strategy.

Since 2003 Landcom has focussed on making sustainability initiatives a key element of all of its developments, as reflected in its annual Triple Bottom Line reporting. Landcom prepared a Water Sensitive Urban Design (WSUD) Policy in 2003 and published its WSUD Strategy in 2004. Since that time Landcom has progressed steadily towards attaining the best practice objectives of urban water management in all its projects. Landcom has implemented a range of innovative WSUD initiatives which have achieved targets beyond the original WSUD strategy.

This document forms part of a 4-book set that updates and revises the Landcom Water Sensitive Urban Design Strategy of 2004. Recent advances in Integrated Water Cycle Management and WSUD, such as the release of Australian Runoff Quality[1], the BASIX scheme, MUSIC (v3) and wider implementation have seen the stormwater industry evolve over the last three years. During this period the NSW Government has also revised its statewide water management objectives for new developments.

Landcom's Water Sensitive Urban Design Strategy (2009) is contained in the following 4 books;

Book 1 | POLICY
- contains Landcom's WSUD Policy and Urban Water Management Objectives

Book 2 | PLANNING AND MANAGEMENT
- consists of descriptions and discussions on urban water best planning and management practices applicable to Landcom projects

Book 3 | CASE STUDIES
- includes discussions on how WSUD could be integrated into Landcom Development Projects

Book 4 | MAINTENANCE
- contains operation and maintenance guidelines of key WSUD elements

This document, Book 2, describes and discusses urban water best planning and management practices applicable to Landcom projects.

[1]Engineers Australia (2006), Australian Runoff Quality: A Guide to Water Sensitive Urban Design, Wong, T H F (ed), ISBN 0 85825 852 8, Engineers Australia, Canberra, Australia, 2006.

2 | Attainment of the Water Conservation Targets

Wetland treatment system | Park Central

Landcom's stretch target recommends a 60+ % reduction in potable water consumption.

Landcom's water conservation target is consistent with the BASIX scheme which requires that new homes in Sydney achieve a 40% reduction in potable water consumption. Landcom's stretch target recommends a 60+ % reduction in potable water consumption. Options to minimise water consumption considered for a development include:

- Demand management – water efficient fittings, appliances (dishwashers and washing machines) and water efficient garden design.
- Alternative Water Sources – greywater / roofwater / stormwater / reclaimed water

Existing residential water use in Sydney is summarised in **Table 1** (Base Case). These figures are based on the average water demand across all types of residential development, including detached, attached and high-rise dwellings. The total potable water demand is, on average, 256.6 Litres per person per day.

As can be seen in **Table 1**, most of this is used in the shower, toilet, washing machine and garden. The numbers given are not meant to be prescriptive but are intended to illustrate how water use can be calculated and how BASIX targets can be met.

Examples of a detached and a high-density dwelling in attaining the BASIX target are also outlined in **Table 1**. These examples both use the average Sydney household water consumption as the baseline. Detached dwellings can meet the BASIX target using water efficient fittings in the kitchen, bathroom and shower, as well as adopting alternative water sources for toilet flushing, garden watering and car washing.

Multi-storey dwellings can meet the BASIX target using water efficient fittings in the kitchen, bathroom and shower, as well as adopting 4 star clothes washing machines and dishwashers, which are allowed under the BASIX scheme for multi-unit residential dwellings.

Detention pond integrated into parkland I Garden Gates

Table 1 I Residential water savings through water efficient fittings and rainwater harvest and/or water recycling[1]

Usage (L/P/d)	Estimated per capita demand*				
	Average for all Sydney homes pre-BASIX	Detached dwellings		High-density/multi-storey	
		Demand Management features	Estimated per capita demand*	Demand Management feature	Estimated per capita demand*
INTERNAL					
Kitchen sink	12	Flow regulator (5*)	6.5	Flow regulator (5*)	6.5
Bathroom basin	5.9	Flow regulator (5*)	3.2	Flow regulator (5*)	3.2
Laundry	5.9		5.9		5.9
Bathroom	8.7		8.7		8.7
Shower	56.9	3 star rated	44.6	3 star rated	44.6
Toilet	35.2	Rainwater/ recycled water	3.5	3 star rated	24.8
Clothes Washing Machine	49.1		49.1	4 star rated	19.1
Dishwasher	3.9	4 star rated	3.9	4 star rated	3.9
SUB-TOTAL INTERNAL	177.6		125.4		112.8
EXTERNAL					
Garden	47.9	Rainwater/ recycled water	4.8		1.9
Swimming Pool	9.3		9.3		
Leaks	12.1		12.1		20
Car Wash	6	Rainwater/ recycled water	0.6		1.3
Cooling Tower	0.5		0		16
Fire Test	3.2	-			
SUB-TOTAL EXTERNAL	79		26.8		39.2
TOTAL	256.6		152.2		152.0

* Predicted demands were estimated from a range of sources, including the Water Efficiency Labelling Scheme (Australian Government)

[1] Determined from the BASIX Scheme, NSW Department of Planning.

Bioretention system on road verge

2.1 Demand Management

Most detached dwellings require efficient fittings as well as a rainwater tank to meet the BASIX Targets.

Demand management measures are relatively easy to implement, even in existing dwellings. Examples include:

- Water efficient fittings, including toilets, shower heads and tap fittings;
- Water efficient appliances, including dishwashers and washing machines (only allowed to contribute to the BASIX score for multi-storey developments);
- Use of pool covers to reduce evaporation losses from swimming pools; and
- Landscaped areas comprised of low-water-use and/or indigenous plants.

As shown in **Table 1**, most detached dwellings require efficient fittings as well as a rainwater tank (or other alternative supply) to meet the BASIX Targets. Normally it is possible to achieve a BASIX score of 40% for high-rise buildings using a combination of water-efficient fittings and appliances, without the use of alternative water sources.

Alternative water sources would increase water savings and may enable high-rise dwellings to meet the stretch target of 60% reduction in potable water demand.

Wetland I Prince Henry

2.2 Alternative Water Sources

In most urban developments there are three major water sources:

1) Potable mains water
2) Local runoff:
   - Rainwater (roof runoff)
   - Stormwater (surface runoff from roads, paths and pervious surfaces such as lawns)
3) Wastewater:
   - Greywater (shower, bathroom and laundry sinks, and washing machine wastewater)
   - Blackwater (kitchen and toilet wastewater)

Rainwater, stormwater, greywater and blackwater can be alternatives to potable water.

Potable water conservation targets (in NSW) are calculated using the BASIX tool. The water reuse options given in the tool are potable mains water, rainwater, stormwater, greywater (treated and diverted), and reticulated (applicable only where a reticulated water supply is available). The allowed application of alternative water streams is summarised in **Table 2**. If greywater (treated or diverted) or stormwater is selected, a warning box in BASIX appears: Greywater systems to toilets, laundry taps, and/or garden taps requires that the greywater is treated to a suitable quality as determined by NSW Health.

Table 2 I ALLOWABLE WATER REUSE APPLICATIONS (BASIX)

SOURCE	REUSE OPTION				
	Garden and Lawn	All toilet	Laundry	All hot	Drinking and other
Townswater	✓	✓	✓	✓	✓
Rainwater	✓	✓	✓	✓	✓
Stormwater	✓	✓	✓		
Greywater (treated)	✓	✓	✓		
Greywater (diverted)	✓				
Reticulated	✓	✓	✓		
Mix of RW, GW & SW	✓				

Rainwater tank

2.2.1 Rainwater

Rainwater is available wherever there is a roof surface from which runoff can be collected. Minimal treatment is required before rainwater can be used. Under the BASIX legislation, the NSW government recommends that rainwater be used for garden watering, cold water laundry and toilet flushing and also accepts that it may be used for hot water. However sometimes there may be insufficient rainwater available to meet the high combined demands of toilet flushing, washing machine and garden watering, and usually potable mains water top-up is provided to rainwater tanks.

2.2.2 Stormwater

Stormwater is runoff from the ground surface and is traditionally conveyed directly to receiving waters. Stormwater treatment and reuse can both save potable water and assist in meeting water quality and flow management objectives in a development. Stormwater contains higher contaminant loads than rainwater, even after it is treated to meet the stormwater quality targets outlined in Book 1, Section 2.2. Therefore some additional treatment, such as disinfection, is typically required prior to reuse. Stormwater reuse is particularly effective on a precinct scale, for example stormwater could be collected for irrigation of public open space in a Landcom development.

2.2.3 Greywater

Greywater reuse can save significant quantities of potable water. Its effective use requires separation of greywater from other wastewater streams and additional infrastructure (underground tanks, pumps, on-site disposal system). While separation and reuse of greywater can have significant benefits, including the reduction of wastewater volumes and reduced potable water demand, the infrastructure requirements for a fourth pipe to separate the greywater for treatment, and the treatment requirements being similar to wastewater mean that greywater reuse may only have limited application.

Greywater treatment and reuse systems can range from a simple greywater diversion system, which directs greywater to a subsurface irrigation system, to a complex treatment system including collection, treatment, storage and possibly disinfection.

Wetland | Helensburgh

2.2.4 Blackwater

Blackwater treatment and reuse options include reclaimed water reuse and sewer mining. In many parts of Western Sydney, Sydney Water is making reclaimed water available to new developments. Wastewater from existing wastewater treatment plants is treated to a higher standard, then it can be delivered to new developments in a dual pipe system.

Reclaimed wastewater can only be used for toilet flushing, garden irrigation, and other outdoor uses. As these uses represent a significant proportion of total household water demand, it is usually possible to meet the BASIX target using reclaimed wastewater along with water efficient fittings. Wastewater reuse for garden irrigation and toilet flushing could be combined with a rainwater tank for laundry and hot water use for a solution that saves additional water and meets the stretch target of 60% reduction in potable water demand.

A wide range of wastewater treatment systems and devices are available, ranging from relatively simple biological systems (constructed ponds and wetlands) to highly technological mechanical devices (membrane filtration and reverse osmosis). The appropriate treatment system for a given application depends on:

- The wastewater stream to be treated – light greywater (including shower, bath and bathroom basin wastewater), greywater (including laundry tub and washing machine wastewater) or blackwater (including kitchen and toilet wastewater).
- The water quality required at the end of the treatment process.
- The wastewater flows – total quantity, variability in quality and quantity.

The report *Wastewater Reuse in the Urban Environment: Selection of Technologies*, prepared by Ecological Engineering for Landcom in 2006, includes detailed information on selecting the right treatment technologies for wastewater treatment.

2.3 Maintenance

Rainwater harvesting systems are relatively low maintenance and simple, regular preventative maintenance can help avoid the need for corrective action.

Demand management options require minimal maintenance, and may even prove to require less maintenance than traditional options. For example:

- Water efficient toilets, shower heads and tap fittings have maintenance requirements no different to traditional less efficient fittings.
- Water efficient appliances including dishwashers and clothes washing machines have similar maintenance requirements to traditional models.
- Pool covers may reduce pool maintenance efforts by keeping leaf litter out of swimming pools.
- Water-efficient landscaping can also be low-maintenance landscaping, as residents will not need to spend so much time watering the garden and tending to plants which are ill-suited to the Australian climate.

Rainwater harvesting systems are relatively low maintenance and simple, regular preventative maintenance can help avoid the need for corrective action. Recommended maintenance includes:

- 6-monthly inspections of roof areas and gutters to ensure they are relatively free of leaves and debris. Vegetation and trees that overhangs the roof may need to be pruned.
- First flush devices should be checked once every 3-6 months and cleaned out as required.
- Screens at inlet and overflow points should be inspected each 6 months to check for fouling.
- Each 2-3 years, tanks should be checked for accumulation of sludge. Sludge may become a problem if it is deep enough to start becoming resuspended or when it affects storage capacity. When necessary, sludge can be removed by siphon, by suspending the sludge and washing it through, or by completely emptying the tank.

Stormwater treatment and reuse systems can take a range of different forms, with different maintenance requirements. Maintenance for vegetated stormwater treatment systems is described in Book 4. Stormwater treatment measures for reuse may also include other types of treatment systems including Gross Pollutant Traps (GPT), sand filters and disinfection systems, which have more intensive maintenance requirements, e.g. GPTs require frequent cleanouts and the surface of sand filters needs to be scraped around once each 3 months. UV disinfection systems need to be checked regularly and the UV lamps need to be replaced occasionally. Stormwater storage systems should be checked for accumulation of sludge, similar to rainwater tanks.

Greywater systems range from simple to complex treatment and reuse systems. Simple greywater diversion systems still require regular maintenance, including (based on the *NSW Guideline for Sewered Residential Premises (Single Households) Greywater Reuse*, Draft for Comment 28 August 2006):

- Regular cleaning of filters (each week).
- Replacing filters (each 6-12 months).
- Periodic de-sludging of the surge tank (each 6 months).

More complex greywater treatment systems have more onerous maintenance requirements, which are set out by manufacturers of greywater treatment systems.

Wastewater treatment generally takes place at a centralised facility, where treatment, monitoring and maintenance requirements are similar to any wastewater and water treatment plants.

2.4 Costs

Water-efficient landscaping can be installed at no additional cost to non-water-efficient landscaping.

Costs for meeting water conservation targets should be balanced against improved receiving water quality and less dependence on potable water systems. For example, residents may value the ability to water their garden with rainwater or reclaimed water, while potable water restrictions are in place.

Demand management measures can be considered cost-neutral, as water efficient fittings and appliances can be used in place of non-water-efficient equivalents at similar prices. Similarly, water-efficient landscaping can be installed at no additional cost to non-water-efficient landscaping. Some demand management measures can even save significant amounts of money, for example efficient shower heads reduce hot water use, which in turn reduces hot water heating costs.

Alternative water sources include some additional costs. Rainwater tanks are readily available and there is information on costs available from suppliers. A good indicative cost to use for a typical household rainwater tank is around $2-3,000, including supply and installation of a simple above-ground tank (slimline tanks or other special designs are likely to be more expensive). Maintenance costs are around $90/year (MUSIC User Manual, 2005). These costs assume that the rainwater tank is plumbed into the house and includes a pump.

Stormwater reuse costs are difficult to summarise in general terms. There are significant economies of scale, depending on the magnitude of the reuse system. Key cost components include the treatment and storage systems. It is best to look at stormwater reuse costs on a site-specific basis.

Greywater diversion and treatment systems range in cost depending on the size and type of the treatment system. In the Landcom report *Wastewater Reuse in the Urban Environment: Selection of Technologies* (2006), two single household greywater treatment systems were included in the analysis and they cost around $5,000-6,500 for supply and installation and <$500 per year for maintenance.

Wastewater treatment costs vary greatly according to the scale of the wastewater treatment and reuse system. In the Landcom report *Wastewater Reuse in the Urban Environment: Selection of Technologies* (2006), the range of costs found for different systems indicate that:

- For single household systems, supply and installation costs are around $5,000-13,000 and maintenance costs are around $300 - 500 per year.
- For systems designed for around 50 people (a cluster of houses), supply and installation costs are around $30,000-60,000 and maintenance costs are around $1,000-1,500 per year.
- For systems designed for around 100-2,000 people (e.g. multi-unit dwellings), supply and installation costs include a range of $100,000-1,500,000 and maintenance costs include a range of $6,000-100,000 per year.
- For major systems designed for a whole subdivision, costs are highly site-specific. Where recycled water is available from Sydney Water, costs may be limited to the installation of the dual pipe system, making this an attractive option where available.

Ponds at the end of the wetland treatment system I Park Central

Golf course stormwater storage I Prince Henry

2.5 Key Issues

Key issues for the implementation of water conservation initiatives are;

- Minimise demand with the use of water efficient fittings and appliances.
- Consider the different sources of water available (e.g. potable, rainwater, recycled water) and match water sources with end uses that have compatible quality requirements.
- Check the availability of recycled water in the region. The use of centralised recycled water systems (dual pipe reticulation) makes it possible to meet BASIX targets without the use of rainwater tanks or to exceed BASIX targets with rainwater tanks.
- Where rainwater tanks are to be provided, tanks should be sized with respect to the available roof area and the anticipated demands.
- Regional stormwater harvesting could be incorporated into developments using tanks or ponds as storage systems, e.g. for irrigation of public open space.
- Greywater recycling is typically more difficult to implement than other options, as it requires separation of greywater from the wastewater stream, but this may warrant investigation where other options are limited.
- A combination of different alternative water sources could make it possible to achieve reductions in potable water demand much greater than 40%. 60% reduction is considered a realistic stretch target that could be achieved using recycled water for toilet flushing and outdoor use, plus a rainwater tank for hot water.

3 | Attainment of the Stormwater Quality Targets

Figure 1 - Examples of bioretention systems in planter boxes, in parks and in the streetscape

Stormwater quality targets can be met through stormwater treatment systems, such as bioretention systems, swales and wetlands.

Landcom's stormwater pollution reduction targets require a 45% reduction in the mean annual load of total nitrogen, 65% reduction in the mean annual load of total phosphorus and an 85% reduction in the mean annual load of total suspended solids. The stretch targets are for stormwater pollution load reductions are of 65%, 85% and 90% respectively.

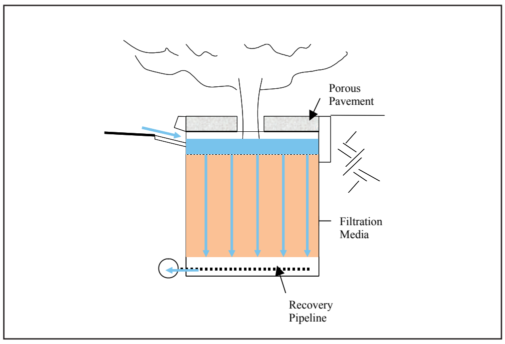
Stormwater quality targets can be met through stormwater treatment systems, such as bioretention systems, swales and wetlands, which can be incorporated into public open space, streetscapes or on lots. Further information on these devices is contained within the NSW Government document *Managing Urban Stormwater: Treatment Techniques*.

3.1 Bioretention Systems

Bioretention systems filter stormwater runoff through a vegetated soil media layer. The treated stormwater is collected at the base of the system via perforated pipes, from where it flows to downstream waterways or storages for reuse. Temporary ponding above the vegetated soil media provides additional treatment. Bioretention systems are not intended to be infiltration systems where treated stormwater would discharge into groundwater.

Typically flood flows bypass the system thereby preventing high flow velocities that can dislodge collected pollutants or scour vegetation. Bioretention systems can be installed at various scales, for example, in planter boxes, in parks or in streetscapes integrated with traffic calming measures. (**Figure 1**).

3.1.1 Street trees



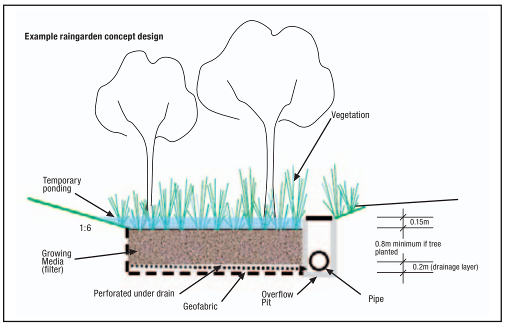
Street tree bioretention systems are small bioretention systems that take the place of traditional street trees. These systems can be integrated into high-density urban environments and can take on a variety of forms (**Figure 2**). A typical arrangement of a street tree bioretention system is shown above. The filtration media should be at least 0.8 m deep to allow for root growth of the tree, therefore substantial depth is required between the inlet and outlet.

Figure 2 - Example of street tree bioretention systems

Figure 3a - Example of bioretention raingarden

Raingardens can be incorporated in a range of locations, as they can be any shape and size.

3.1.2 Raingardens



Raingardens can be incorporated in a range of locations, as they can be any shape and size. Typical locations include pocket parks, traffic calming measures and between parking bays. Examples and a typical raingarden arrangement is shown in **Figures 3a & 3b**.

3.1.3 Bioretention swales

Swale bioretention systems provide both stormwater treatment and conveyance functions. A bioretention system is installed in the base of a swale, whereby the swale provides stormwater pretreatment to remove coarse to medium sediments. The bioretention system can be installed in part of a swale, or along the full length of a swale, depending on treatment requirements. Runoff can be directed into conveyance bioretention systems either through direct surface runoff (eg. with flush kerbs) or from an outlet of a pipe system. An example of these systems is shown in **Figure 4**.

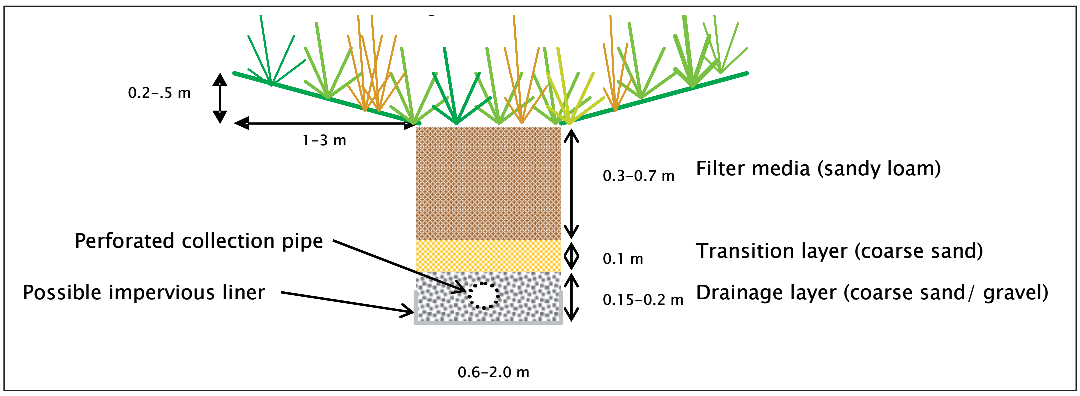


Figure 4 - Example of bioretention swales

Figure 3b - Example of bioretention raingarden

3.1.4 Sizing bioretention systems

Figure 5 presents sizing curves for bioretention systems in Eastern and Western Sydney, showing typical performance for different catchment impervious fractions including 40, 60, 80 and 100%. Different curves are provided for Eastern and Western Sydney to accommodate the influence of different rainfall patterns and volume on treatment performance. The sizing curves are presented in terms of the bioretention filter area as a percentage of the total catchment area.

The curves assume that the bioretention system included 0.2m extended detention, 0.5m filter depth, and a sandy loam filter material, with a median particle size of 0.5mm and hydraulic conductivity of 100mm/hr. It can be seen in **Figure 5** that in Western Sydney a bioretention system to treat a 40% impervious catchment can be sized at approximately 1% of the catchment, whereas this increases to 1.5% in Eastern Sydney. For catchments with higher impervious fractions, a larger treatment area is required; at 100% impervious fraction, 1.5% of the catchment is required in western Sydney and 2.1% in eastern Sydney.

Other than the area, key aspects of bioretention system design that have a strong influence on pollutant removal performance include the extended detention depth, filter media depth and type of filter material. Bioretention performance improves with increasing depths of extended detention and the filter media, however deeper systems may not be feasible on all sites.

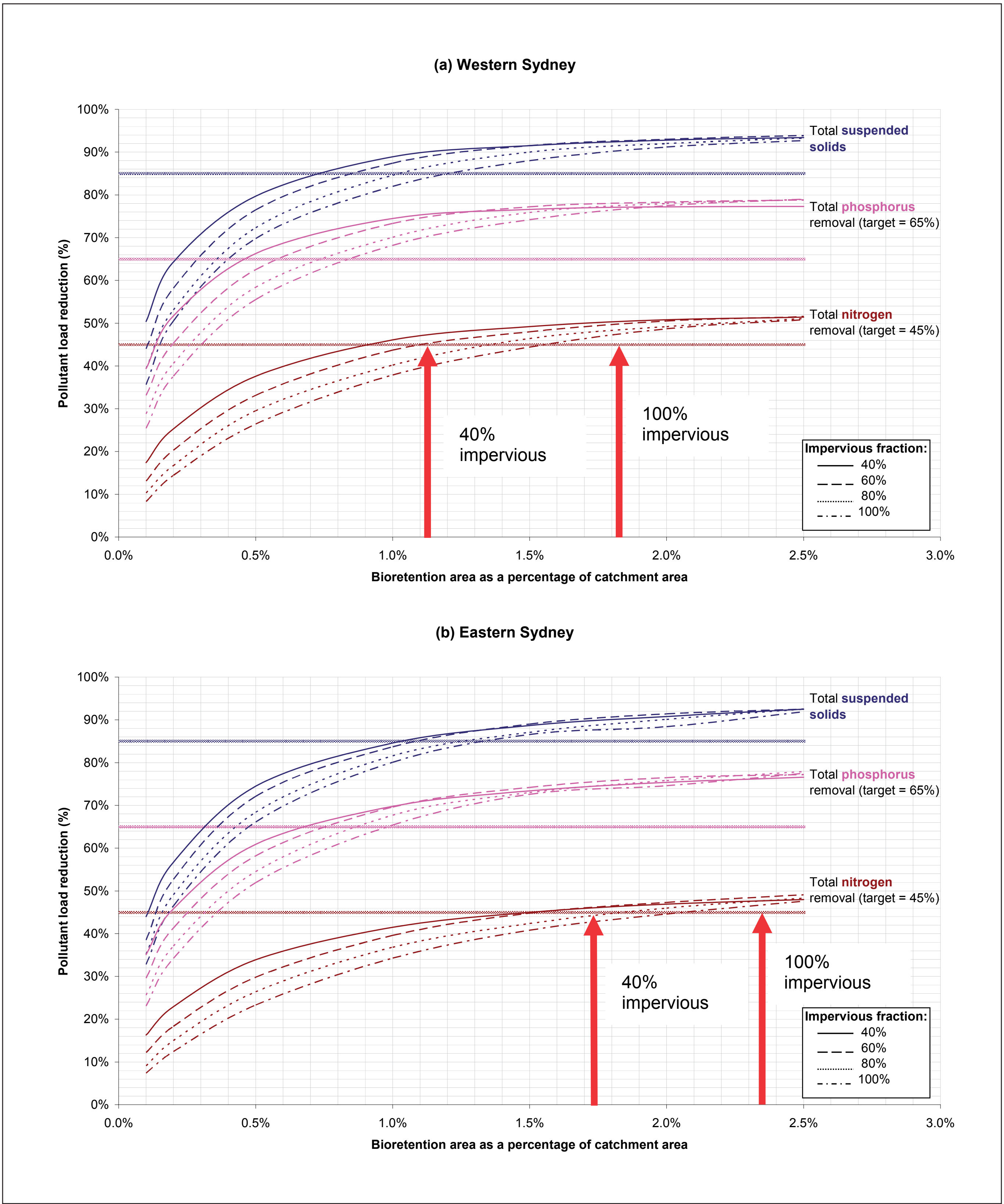


Figure 5 - Bioretention sizing curves

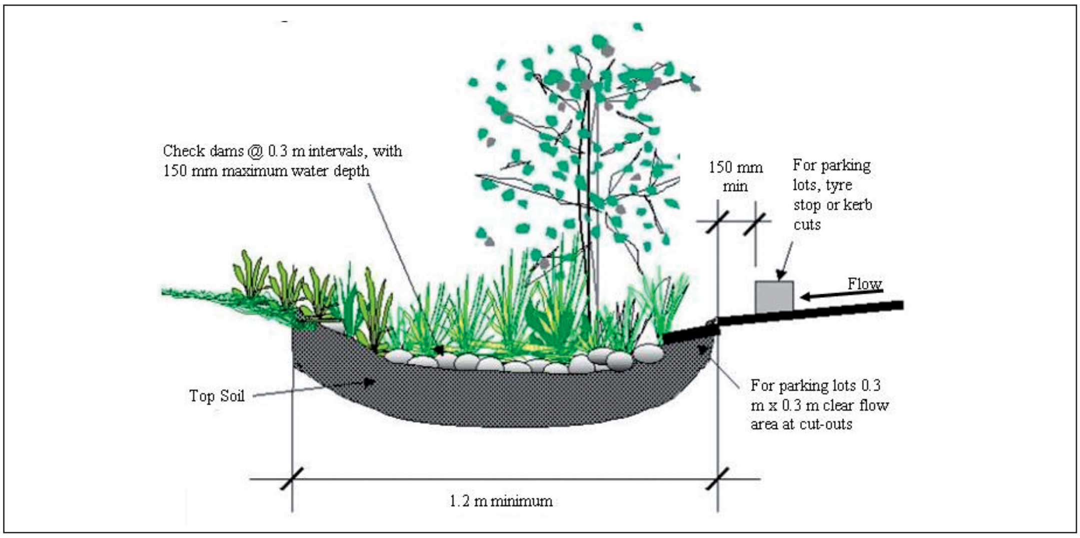


Figure 6 - Swale cross-section

3.2 Vegetated Swales and Buffer Strips

Vegetated Swales and Buffer Strips can be integrated with landscape features in public open space, or incorporated into streetscapes.

Vegetated swales can be used instead of pipes to convey stormwater and provide a 'buffer' between the impervious areas of a catchment and the receiving water. They can be integrated with landscape features in public open space, or incorporated into streetscapes. The interaction with vegetation facilitates an even distribution and slowing of flow, thus encouraging pollutant settlement and retention in the vegetation. A typical swale cross-section is shown in **Figure 6**.

The longitudinal slope of a swale is an important consideration. They generally operate best with slopes from 1% to 4%. Slopes milder than this can tend to become waterlogged and have stagnant ponding, although the use of underdrains can alleviate this problem.

Figure 7 demonstrates the different forms that vegetated swales can take.

Figure 7 - Examples of different types of swales

3.2.1 Sizing swale systems

Swales can be constructed in a variety of sizes and configurations. For simplicity and ease of use, a set of sizing curves have been produced for one type of swale with typical cross-sectional dimensions and other parameters:

- Longitudinal slope = 3%.
- Base width = 2 m (top width dependent on depth of flow).
- Side slopes = 1 in 6.
- Vegetation height = 0.25 m.

The sizing curves are presented in terms of the length of this standard swale per hectare of contributing catchment.

Four sets of results are presented, for catchment impervious fractions of 40, 60, 80 and 100%. Sizing curves for a standard swale are shown in Figure 8.

Other than their length, key aspects of swale design that influence their pollutant removal performance are the slope and vegetation height. The swale cross-sectional area is also important and needs to be large enough to convey the design flow.

It can be noted that swales by themselves are not capable of meeting the stormwater pollution reduction targets and therefore need to be accompanied by another treatment system such as a bioretention system or a wetland.

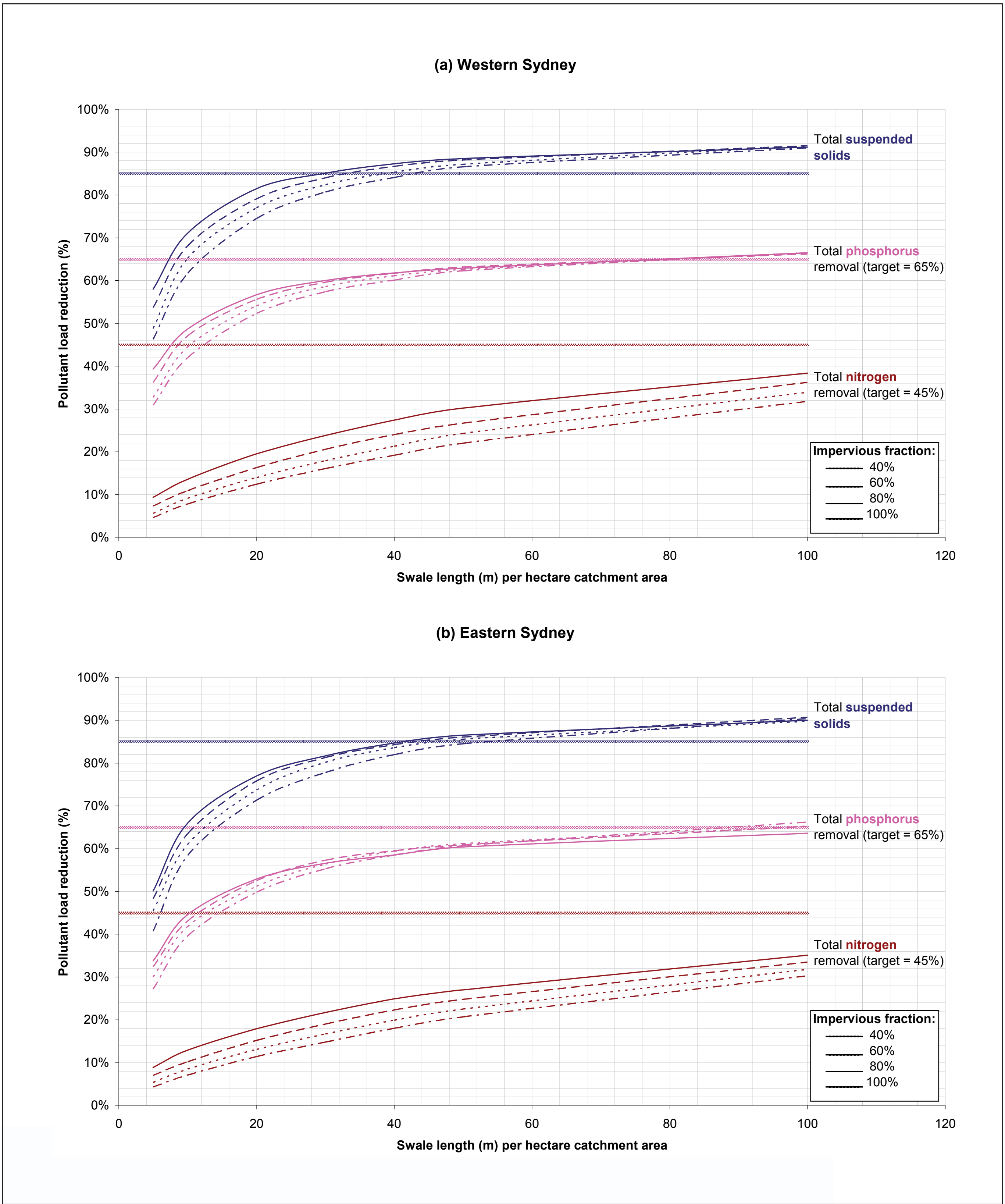


Figure 8 - Swale sizing curves

3.3 Wetlands

While wetlands can play an important role in stormwater treatment, they can also have significant community benefits.

Constructed wetland systems remove pollutants through sedimentation and absorption of nutrients and other associated contaminants. They generally consist of an inlet zone (a sediment basin to remove coarse sediments), a macrophyte zone (a shallow heavily vegetated area to remove fine particulates and take up soluble pollutants) and a high flow bypass channel (to protect the macrophyte zone).

While wetlands can play an important role in stormwater treatment, they can also have significant community benefits. They provide habitat for wildlife and a focus for recreation, such as walking paths and resting areas. They can also improve the aesthetics of new developments and can be a central landscape feature.

Wetlands can be constructed on many scales, from small scales, house block scale to large regional systems. In highly urban areas they can have a hard edge form and be part of a streetscape or building forecourts. In regional settings they can be over 10 hectares in size and provide significant habitat for wildlife.

3.3.1 Macrophyte zone

An important operating characteristic of macrophyte zones is well distributed flows that pass through various bands of vegetation. Strong vegetation growth is required to perform the filtration process as well as withstand flows through the system. Different bands of a wetland are shown in **Figure 9**.

Different zones in a macrophyte system perform different functions. Ephemeral areas are often used as organic matter traps. These areas wet and dry regularly and thus enhance the breakdown process of organic vegetation. Marsh areas promote epiphyte (biofilms) growth and filtration of runoff. Epiphytes use the plants as substrate and can effectively promote adhesion of fine colloidal particulates to wetland vegetation and uptake of nutrients. Generally, there are areas of open water surrounding the outlet of wetlands. These can increase UV disinfection and provide habitat for fish and other aquatic species.

Optimal detention times in the wetland (typically designed for 72 hours) ensure desired performance. The macrophyte zone outlet must be sized accordingly. Multiple level orifice riser outlets are considered to give the most uniform detention times for wetlands.

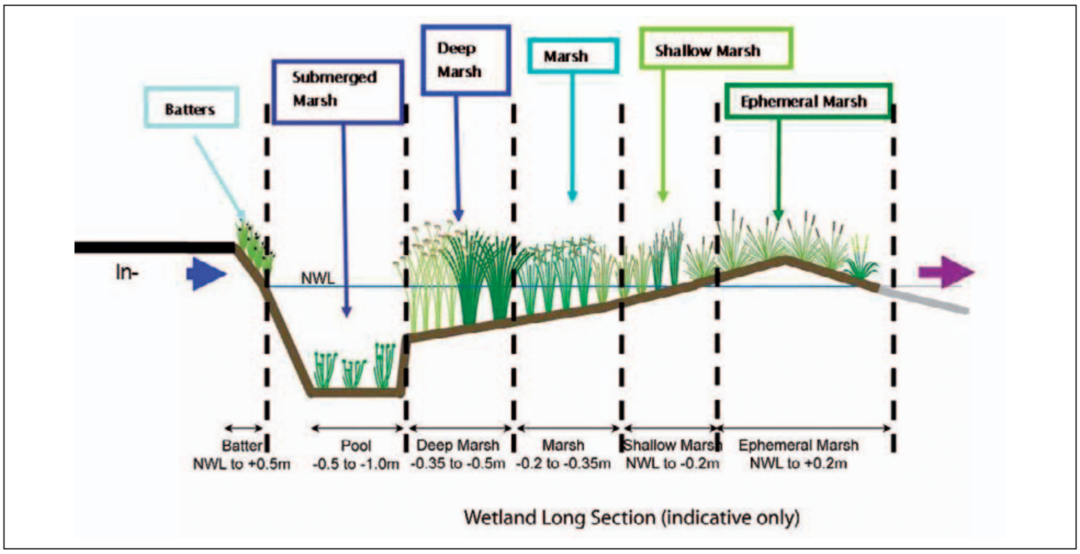


Figure 9 - Indicative long section for a wetland.

Figure 10 - Examples of wetlands in highly urban areas

3.3.2 Sizing wetland systems

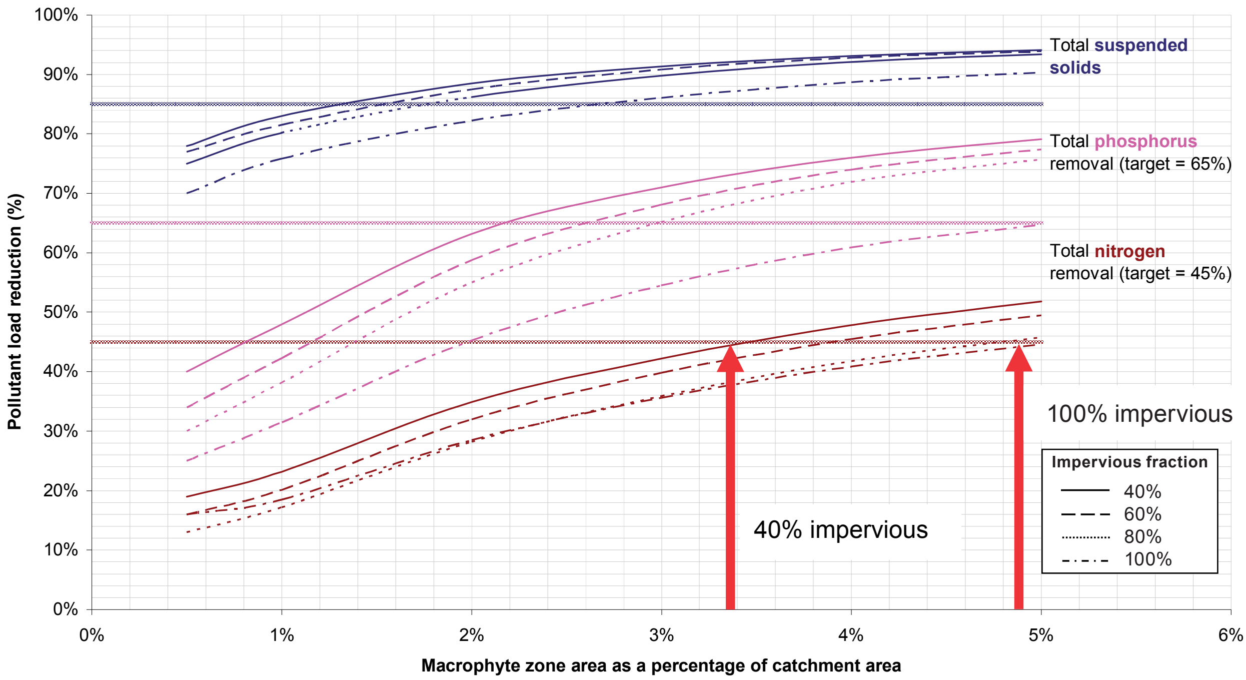
Sizing curves for wetlands in Eastern and Western Sydney are presented in **Figure 11**, showing typical performance for different catchment impervious fractions from 40 to 100%. The sizing curves present the wetland's macrophyte zone area as a percentage of the catchment area. The total area set aside for the wetland would also need to include the sedimentation basin and high flow bypass; therefore the total area for the wetland would need to be greater.

The sizing curves are based on a wetland with the following characteristics: there is a suitably sized GPT upstream of the wetland to provide efficient coarse sediment removal, or a treatment system able to perform the equivalent removal of gross pollutants and coarse sediments, such as a suitably sized swale.

A wetland always requires a sediment basin at its inlet. The sediment basin should be sized appropriately, even if space for the wetland is limited. The standard sediment basin used in producing the curves a standard size of 10% of the macrophyte zone of upstream catchment and a typical pool depth of 2m. The wetland has an average depth of 0.5 m and an extended detention depth of 0.5 m. The extended detention allows more stormwater to be captured and treated, thus increasing the pollutant load removed. The wetland has been sized for 72 hours detention. Evaporation losses are 125% of potential evapo-transpiration.

It is generally preferred that the ratio of length to width in a wetland is approximately > 1:4 and < 1:10. Wetland cells with irregular shapes should have berms to regulate the flow. Other than the macrophyte zone area, key parameters of wetland design that have an impact on performance include the size of the sedimentation basin, the extended detention depth and the detention time.

The pollutant removal rates in the sizing curves in **Figure 11** are for the whole treatment train, including the GPT, sedimentation basin and wetland. The sizing curves show that the macrophyte zone size should be 1.6-4.0% of the catchment area in Western Sydney and 3.0-5.0% of the catchment area in Eastern Sydney, depending on the impervious fraction.



(b) Eastern Sydney

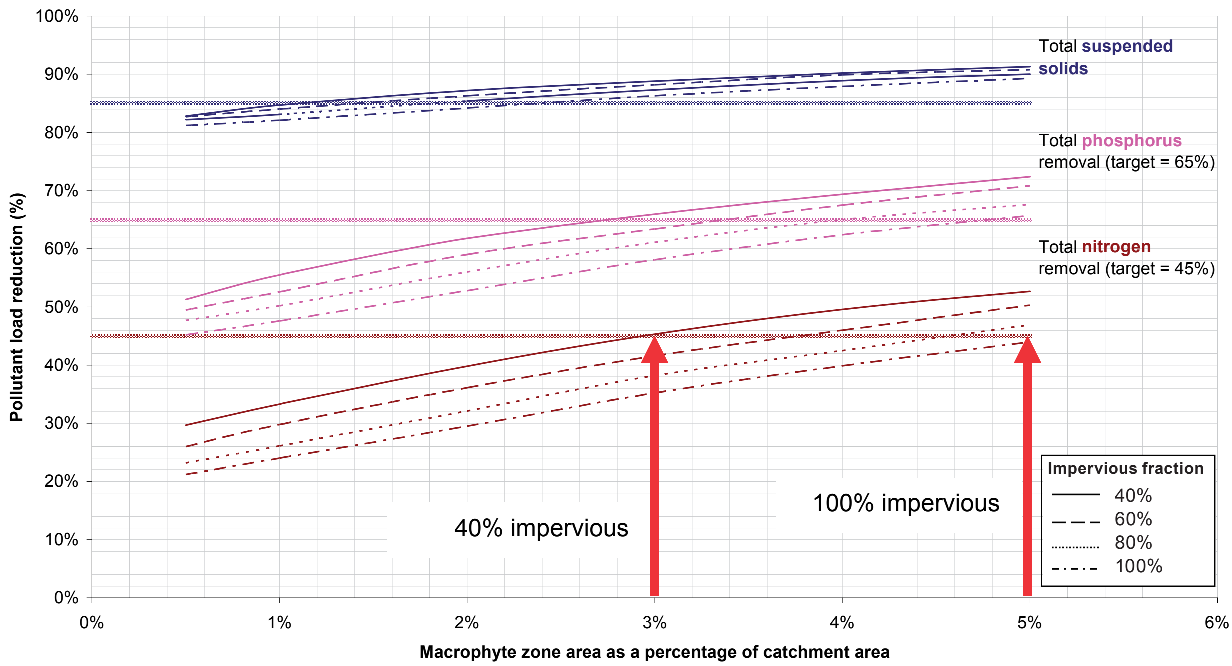


Figure 11 - Wetland sizing curves

Riparian and channel restoration | The Ponds

3.4 Key Issues

Key issues for the implementation of stormwater quality initiatives are;

- Use stormwater treatment elements in the urban landscape to maximise the visual and recreational amenity of developments.
- Size WSUD elements relative to the contributing catchment area and impervious fraction, as demonstrated in the sizing curves presented in this section.
- Generally, WSUD is most effective on slopes of 1-4%.
- Where slopes exceed 4%, either discrete treatment systems such as bioretention street planters or additional flow control features (such as check dams in swales and bioretention swales) can be used.
- Use WSUD elements such as wetlands and bioretention raingardens in open space areas where practical.
- Use WSUD elements such as bioretention swales in streets on the high-side verge reserve if there is one, or in the centre median of dual travel-way streets. WSUD elements such as bioretention raingardens can also be incorporated between parking bays or in traffic-calming features.
- It is generally preferred that the ratio of length to width in a wetland is approximately > 1:4 and < 1:10. Wetland cells with irregular shapes should have berms to regulate the flow.

4 | Attainment of the Flow Management Targets

Integrating treated water into the landscape

A commonly adopted best management practice (BMP) guidelines for waterway stability include the stipulation that peak flows from the 1.5-year average recurrence interval (ARI) storm event post-development must be attenuated to pre-development levels (ARQ, 2006).

The NSW Department of Environment and Climate Change (DECC) have recently recommended the SEI for designated 'growth centres' in western (greater) Sydney as a measure of the impact development can have on geomorphic stability of the downstream waterway. The Stream Erosion Index has been defined by DECC as the ratio of the post development duration of stormwater flows greater than the "stream-forming flow" to the duration of flows greater than the "stream-forming flow" for the catchment under pre-development, natural conditions. The flow management targets for new developments require a Stream Erosion Index = 3.5 – 5.0.

The flow management target is applicable to Greenfield sites in Western Sydney or at other sites where there is a natural stream categorised by Department of Water & Energy (DWE), downstream of a development. At other sites, flow management objectives should be considered on a case-by-case basis.

4.1 Adequacy of Proposed NSW SEI Objectives

Theoretical basis for determining stream erosion potential suggests that stream erosion is not determined just by the duration of exceedence of the channel forming flow but also the magnitude of this exceedence. The erosion potential is often expressed as a power function (of 1.5) of the magnitude of exceedence of the critical shear stress condition in the waterway.

SEI modelling undertaken by Brookes and Wong (2009) indicated that a typically developed catchment with percentage imperviousness of up to 95% could achieve the prescribed SEI objective of 3 to 5 in the absence of stormwater detention measures. The result is inconsistent with field observations that indicate that unattenuated flows from a developed catchment are a significant cause of creek instability. The adequacy of the SEI target was further tested on three case sites which were currently experiencing stream erosion. The SEI values in two cases were calculated as being within the prescribed range of 3 to 5, suggesting that no stormwater management initiatives for waterway geomorphic protection would have been required. The third case had an SEI greater than 5.

The results identify that the recommended acceptable SEI values of 3 to 5 for the growth centres in Western Sydney may not be adequate in protecting geomorphic stability of stream in the region. It is recommended that the acceptable range of SEI prescribed to mitigate the impacts of land developments be reviewed. It is envisage that further field based investigations may be required to ensure the provide a stronger linkage between the selection of channel forming flow and catchment geology, and in further refining the acceptable range in SEI that reflects best practice approach to WSUD.

In the interim, it is recommended that best practice SEI be set at 2 and a stretch target SEI of 1, while maintaining its current flow management objective of attenuating the peak 1.5 year ARI peak discharge to the pre-development magnitude.

4.2 Basis for Flow Management Targets

Urban development increases the frequency and magnitude of runoff into local watercourses. The reasons for this are outlined in **Table 3**, which explains the key differences between stormwater flow regimes for natural and developed catchments.

Table 3 | Differences in the stormwater flow regime for natural and developed catchments

Catchment conditions	Natural conditions	Traditional developed conditions
Impervious areas and hydraulic connectivity	Few impervious areas, none connected directly to receiving waters	Extensive impervious areas, directly connected to receiving waters via the stormwater pit and pipe network
Rainfall losses (rainfall that does not lead to runoff)	In small storm events, or in the initial part of large storm events, significant quantities of rainfall are stored in depressions, vegetation, and leaf litter. During a storm event, rainfall infiltrates into the upper soil horizons. Rainfall losses are therefore high.	Impervious areas store almost no rainfall. Pervious areas in the urban environment also store less rainfall than natural pervious areas. There are limited opportunities for infiltration during storm events. Rainfall losses are therefore low.
Catchment response time	Relatively slow due to high rainfall losses and indirect connection to receiving waters	Relatively fast due to low rainfall losses and direct connection to receiving waters
Runoff volume	Relatively small due to high rainfall losses	Relatively large due to low rainfall losses
Peak flows	Relatively low due to slow catchment response	Relatively high due to fast catchment response

Example of a grassed swale

One of the important implications of the various flow regime changes outlined in **Table 3** is that urban development leads to a situation where a rainfall event is more likely to lead to runoff. Small, frequent rainfall events in a natural catchment are mostly accounted for in rainfall losses and runoff is infrequent. The same rainfall events in a developed catchment lead to significant runoff in receiving waters.

Typical storm hydrographs for a catchment before and after development are shown in **Figure 12**. Also shown in **Figure 12** is a typical hydrograph for a developed catchment with traditional flood retarding measures (for example, on-site detention or regional flood retarding). Detention is able to reduce the peak flows below pre-development levels, but the volume of runoff and the flow duration remains much larger than in the natural case.

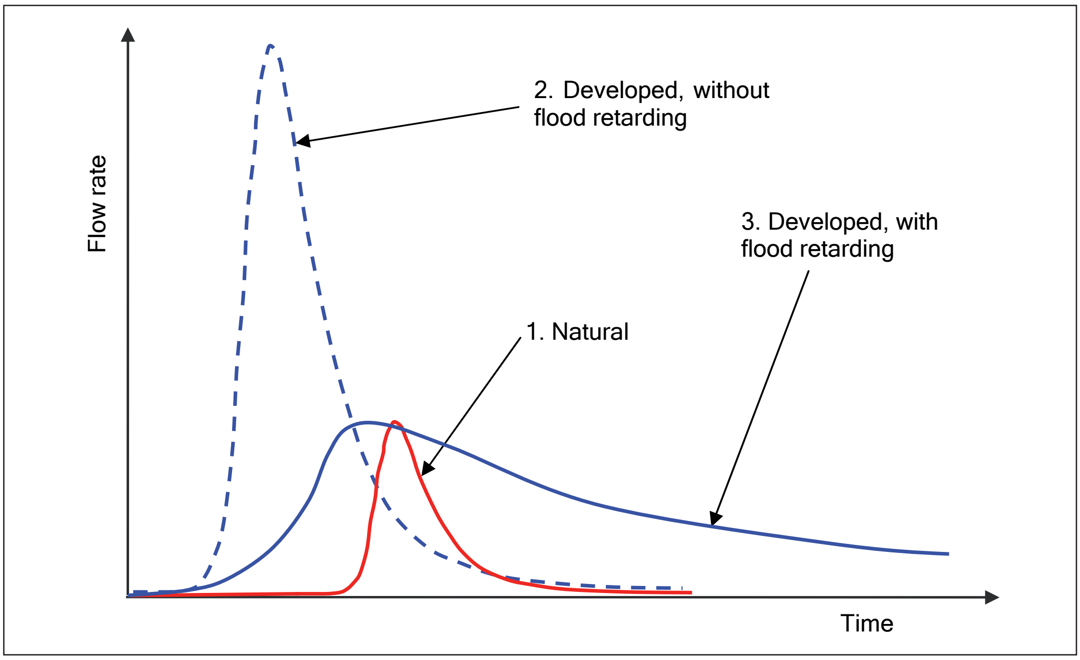


Figure 12 - Typical storm flow hydrographs before and after development

Stream-forming flow is a flow rate at which flow velocities cause sediment movement.

The increase in the frequency and magnitude of runoff post-development and the increased duration of runoff as a result of flood retarding tends to lead to increased erosion in waterways, due to flow in creeks reaching the "stream-forming flow", at which velocities are erosive, more often. Stream-forming flow is a flow rate at which flow velocities cause sediment movement.

The flow management targets outlined in **Book 1, Table 1** refer to the duration for which flows are above the stream-forming flow. This is illustrated in **Figure 13**. The Stream Erosion Index also referred to in **Book 1, Table 1** is the ratio of the post-development duration to the natural duration shown in **Figure 13**. The Stream Erosion Index should be 3.5–5.0 to meet the target or as low as 1.0 to meet the stretch target.

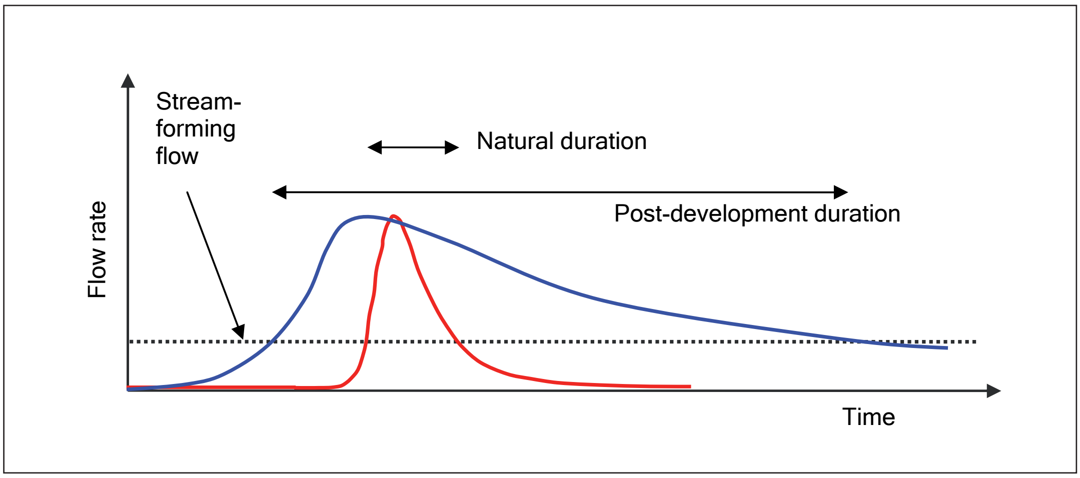


Figure 13 - Duration of flows above the stream-forming flow in natural and developed conditions

Reducing the duration of stream-forming flows to meet the Stream Erosion Index target of 3.5 - 5.0 requires consideration of site-specific issues. Some potential options for meeting the target include:

- Infiltration measures can be an effective way to mimic rainfall losses in natural systems; however infiltration measures are not suitable at sites with salinity, shallow groundwater or shallow bedrock. Much of Western Sydney is affected by salinity and infiltration is unsuitable.
- Storage and reuse can also mimic rainfall losses, for example the use of rainwater tanks or stormwater storage and reuse systems.

An appropriate solution for a site should be determined by modelling. Rainfall-runoff modelling allows determination of the duration of flows above the stream-forming flow, and can be used to model different scenarios including mitigation options.

It is a difficult exercise to define the stream forming flow for different creeks, as it is important to consider the nature of the bed sediment and how susceptible it is to erosion.

5 | Integration of WSUD into Landcom Development Projects

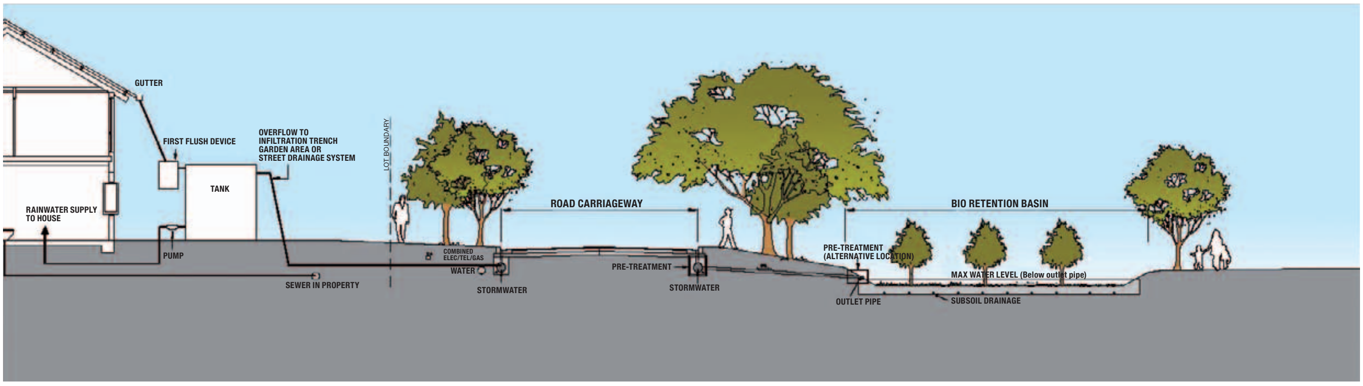


Figure 14 - Configuration of WSUD elements from the household allotment through roads and regional bioretention basin.

Importantly it is recommended that the development of a WSUD strategy be undertaken at the same time as the masterplan.

Every Landcom development is required to have a WSUD strategy to address the management of the three urban water streams through the development. While the complexity of these strategies may vary depending on the scope of the project it is always recommended that this work be undertaken by a specialist consultant.

Importantly it is recommended that the development of this strategy be undertaken at the same time as the masterplan / structure plan to ensure that all WSUD opportunities can be taken and that the strategy is fully integrated into the masterplan. While WSUD elements may have a landtake of 1-3% of the site area, implementing them into the urban design can optimise outcomes, due to:

- WSUD elements being integrated into streetscapes
- WSUD in Public Open Space (POS)
- WSUD elements acting as an interface between the development and the riparian zone
- WSUD at the lot level and delivered through housing design guides.

By integrating WSUD through a development it is possible to make sure that the elements do not require larger areas at downstream locations in developments. The integration of WSUD into Landcom developments is an iterative process involving the masterplanner and the project team. Ideally, this integration will be facilitated through close communication with the masterplanner and through a series of workshops on the selection of WSUD options that meets the design objectives.

An example of the application of WSUD elements through a development is shown in **Figure 14**. Details of the integration of WSUD into POS and roadways are detailed in the following sections.

Figure 15 - Examples of matching public open space with stormwater features (Victoria Park, Docklands in Melbourne and Ascot Waters in Perth. Ascot Waters images source: www.wsud.org)

5.1 Public Open Space (POS) Layout

POS areas can potentially incorporate stormwater conveyance and treatment systems as landscape features within a multiple use corridor.

Integration of public open space (POS) with conservation corridors, stormwater management systems and recreational facilities is a fundamental objective of WSUD. POS areas can potentially incorporate stormwater conveyance and treatment systems as landscape features within a multiple use corridor. This can provide a recreation focus (such as a linear park with bike path or an urban forest) as well as enhancing community understanding and regard of stormwater as a valuable resource. The key principles to be considered in locating POS areas:

- Align POS along natural drainage lines
- Protect/enhance areas containing natural water features (such as creeks and wetlands) and other environmental values by locating them within POS
- Utilise POS to provide links between public and private areas and community activity nodes

For water sensitive landscape design the following natural landscape values should be considered:

- Retention of natural features – watercourses, landforms and other water features should be retained or restored
- Use of indigenous species – existing native vegetation needs to be retained or restored. Vegetated links should be provided with native vegetation on adjoining land
- Planting – should be limited to locally indigenous species (or specifically appropriate other species) and exclude groups that can cause weed problems
- Fauna habitat – provision should be made for fauna habitat measures such as wetlands, ponds, shrubs and nest boxes, and
- Hydrologic maintenance of natural regime on native vegetation – stormwater runoff should be diverted away from native vegetation to maintain suitable soil moisture and nutrient conditions and avoid the spread of weeds.

Figure 16 - WSUD elements can form part of the streetscape

5.2 Road Layouts and Streetscaping

Street layouts on Landcom projects are guided by the Landcom Street Design Guidelines.

Roads account for a significant percentage of the overall impervious area created within a typical urban development and therefore can significantly change the way water is transported through an area. These areas also generate a number of water borne stormwater contaminants that can adversely impact on receiving waterway health (e.g. metals and hydrocarbons). Consequently, it is important to mitigate the impact of stormwater runoff generated from road surfaces. By carefully planning road alignments and streetscapes, WSUD drainage elements such as bioretention systems and vegetated swales can be used to collect, attenuate, convey and treat the runoff before discharge to receiving waterways.

Street layouts on Landcom projects are guided by the Landcom *Street Design Guidelines*. Key principles in selecting road alignments and streetscapes for WSUD depend on the natural topography and overall masterplan for the development, as outlined in the design principles and common issues included in the *Street Design Guidelines*:

- Generally, WSUD elements in the streetscape are most effective on slopes of 1-4%, i.e. where road grades are 1-4%.
- Where slopes exceed 4%, either discrete treatment systems such as bioretention street tree planters or additional flow control features (such as check dams with swales and linear bioretention systems (**Figure 16**) can be used.
- Use WSUD elements such as bioretention swales on the high-side verge reserve if there is one.
- Where the street runs perpendicular to the contours, use either verge for bioretention systems.
- Where practical, incorporate WSUD elements in the centre medial of dual travel-way streets.
- Ensure street or driveway crossovers of bioretention swales are either at grade or incorporate a culvert crossing. If this is not possible, use discrete WSUD elements separated by driveway crossovers.

Figure 17 - Bollards or kerbs with regular breaks allow distributed flow to the WSUD element while protecting these systems from traffic

- Street-scale WSUD elements should be part of an overall WSUD strategy for a development (**Figure 16**).
- It is not necessary to provide WSUD elements on all streets, however streetscape WSUD elements may form an important part of a WSUD strategy for a development.
- Parking areas can be located adjacent to WSUD elements, but should be designed to prevent vehicles damaging these systems. Bollards or kerbs with regular breaks are required to allow distributed flow to the WSUD element (**Figure 17**).
- Parking areas may be interspersed between WSUD elements, such as parking bays between raingardens.

An example of a road cross-section is shown in **Figure 18**.

Different types of streets will lead to different opportunities for WSUD. Model street types described in Landcom's *Street Design Guidelines* are listed in **Table 4** along with potential WSUD opportunities.

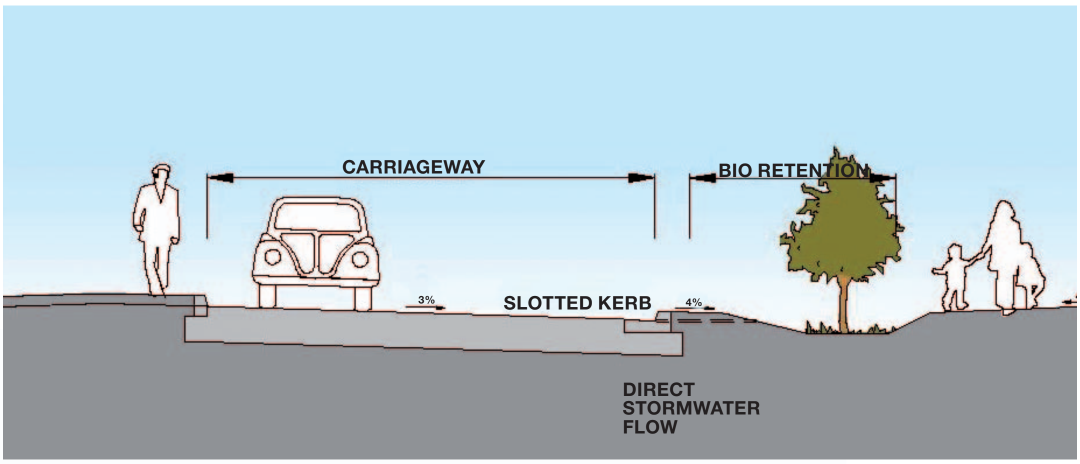
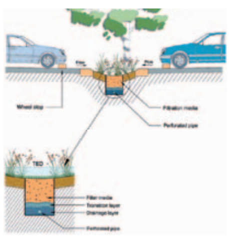


Figure 18 - Road design with stormwater feeding into a bioretention system for treatment.

Table 4 | WSUD opportunities in different streetscapes

Model Street Type	WSUD Examples	
Major Road	Street Tree Bioretention Systems 	Swales/Bioretention Swales In A Central Median 
Collector Street	Raingardens 	Swales/Bioretention Swales 
Local Streets	Swales/Bioretention Swales 	Swale 
Minor Local Street	Bioretention System 	Swales/Bioretention Systems 
Lanes and access ways/mews	Raingardens 	Porous Paving Infiltration 
Carparks		

Detention Basin I Koala Bay

Water steps I Victoria Park

5.3 Application of WSUD Elements

The development of the WSUD strategy will identify which elements are appropriate on any given site.

As outlined there are a range of WSUD planning practices and elements that can be applied to meet water quality objectives. The applicability of these elements at different scales is outlined in Table 5.

The development of the WSUD strategy will identify which elements are appropriate on any given site. Every location or site will require individual design measures. Examples of the application of WSUD are shown in four case studies in **Book 3** I Case Studies.

Table 5 I The application of WSUD elements at varying scales.

ALLOTMENT ⟷	SUBDIVISION ⟷	REGIONAL ELEMENTS
Allotment density and layout	Street layout and streetscape	Public open space Multiple use corridors
AAA appliances	Water use education	Water use education
On-site infiltration	Precinct infiltration	
Buffer strips	Buffer strips	
Vegetated swales	Vegetated swales	Rehabilitated waterways
Bioretention systems	Bioretention systems	Bioretention systems
Rain gardens/ local wetlands	Urban forest	Urban forest
On-site detention	Retarding basins	Retarding basins
Rainwater tanks for reuse	Wetlands and ponds for storage and reuse	Wetlands and ponds for storage and reuse
Grey water reuse	Grey water reuse	Reclaimed water reuse

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